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(54) **Self-starting two-pole single-phase synchronous motor**

(57) In order to facilitate manufacture of a self-starting two-pole single-phase synchronous motor (1) comprising a permanent magnetic rotor (6) which, as a result of diametrical magnetization (9), has two opposite pole faces on its circumference (10), the rotor is made of a plastics-bonded anisotropic magnetic material. The two opposite pole faces (14, 15) each extend at the rotor circumference for a distance which subtends an angle of less than 90° at the rotor axis (5). Details of the apparatus for magnetising the rotor in this way are included.

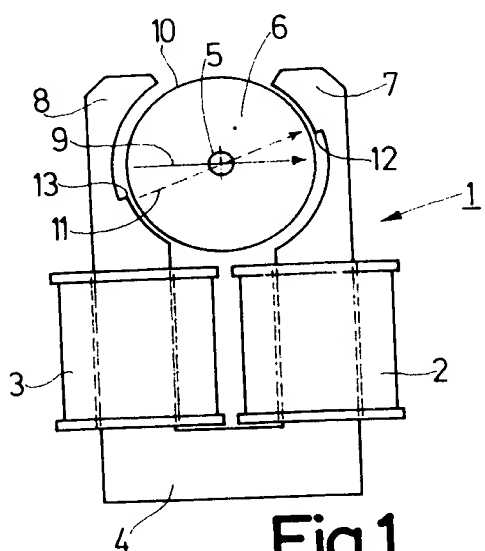

Fig.1

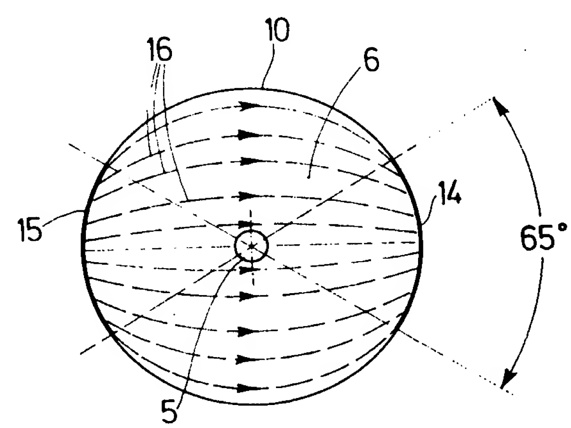

Fig.2

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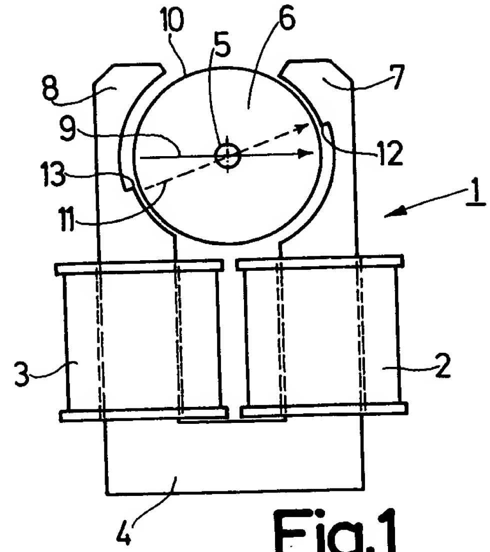

Fig.1

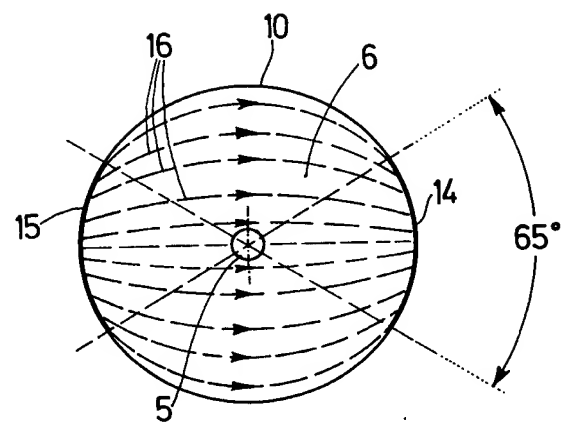

Fig.2

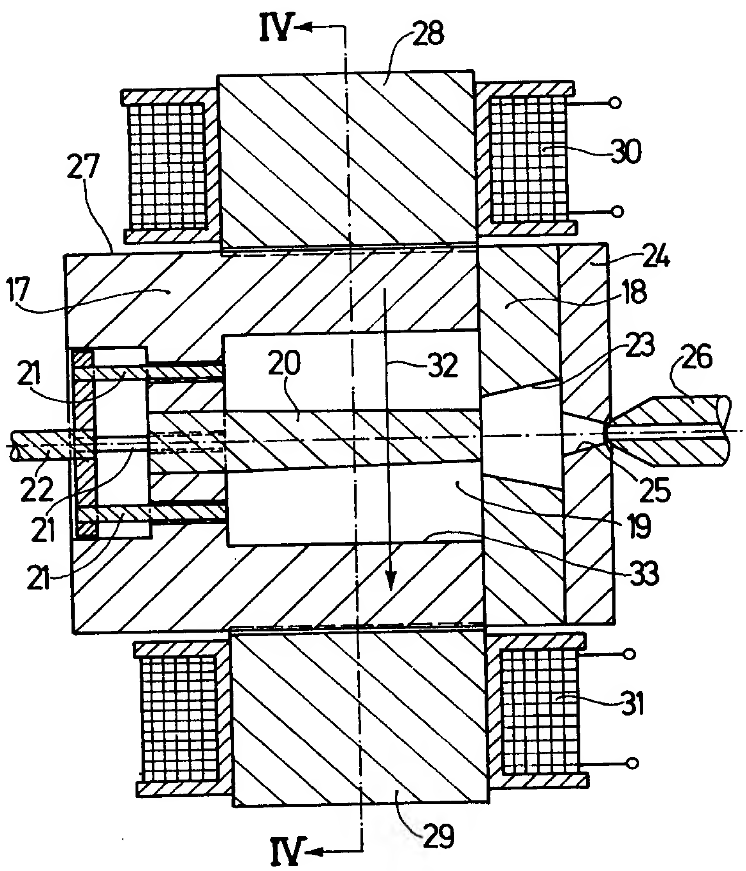

Fig.3

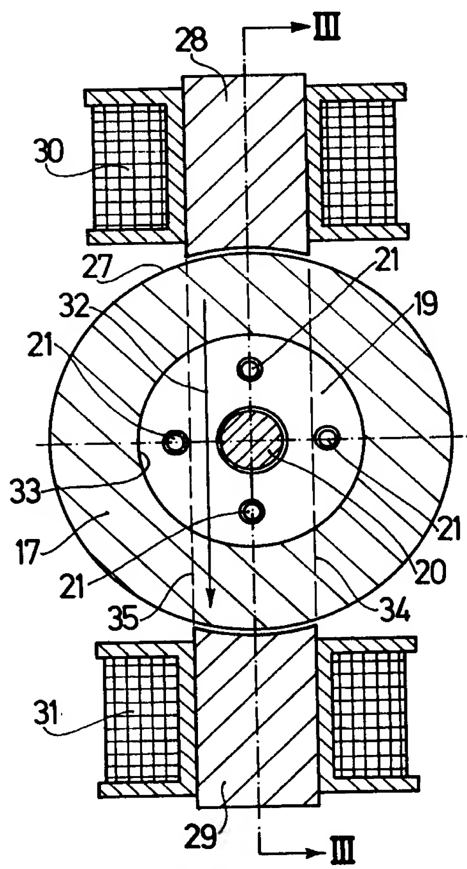

Fig.4

An embodiment of the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawing, in which

Figure 1 is a plan view of a self-starting two-pole single-phase synchronous motor,

Figure 2 shows the rotor of the synchronous motor of Figure 1 on an enlarged scale, the magnetization of the rotor being represented schematically,

Figure 3 is a longitudinal section of a tool for manufacturing a rotor as shown in Figure 2, and

Figure 4 shows the tool of Figure 3 in a sectional view taken on the line IV-IV in Figure 3.

In Figure 1 a self-starting two-pole single-phase synchronous motor 1 comprises a stator 4 provided with an exciter coil comprising two coil sections 2 and 3, and a rotor 6 which is rotatably journalled on a shaft 5, the bearing arrangement of the rotor, which may be constructed in known manner, not being shown for the sake of simplicity. The U-shaped stator 4 comprises limbs 7 and 8, which partly surround the rotor 6 in accordance with an arc, thus forming air gaps. The cylindrical rotor 6, which is made of a magnetizable permanent-magnetic material, is of the two-pole type, for which purpose it is diametrically magnetized, as is schematically represented by the arrow 9. Thus, on its circumferential surface 10 the rotor 6 comprises, diametrically opposite each other, an N-pole and an S-pole, which together constitute a pole pair. Thus there are two 180° rotationally spaced positions of the rotor 6 in which the driving torque of the synchronous motor passes through the value zero. These positions are reached when the magnetic field of the rotor 6 extends transversely of the limbs 7 and 8 of the stator 4, as is indicated for one position by the arrow 9 in Figure 1. As a result of this, it is required that the rotor 6 always acquires either of two specific rest positions which are also 180° spaced from each other, but which have an angular position which differs slightly from the rotor positions in which the driving torque passes through the value zero, in order to enable self-starting to always occur. Since the two positions of the rotor corresponding to zero driving torque and the two rest positions of the rotor are each rotationally spaced from each other by 180°, they are perfectly equivalent, so that only one of these positions need be referred to.

In practice the angular deviation of the rest positions of the rotor 6, one of which is represented by the dashed arrow 11 is Figure 1, from the rotor positions in which the driving torque passes through the value zero will normally lie in the range 10° to 25°, as is apparent from the orientation of the arrows 9 and 11 in Figure 1 relative to each other. The rest positions are obtained by appropriately shaping the parts of the limbs 7 and 8 which face the rotor 6, so that non-uniform air gaps are obtained. Thus, for example, projections 12 and 13 may be formed on the limbs, as is shown in Figure 1. The result is that, in conjunction with the magnetic rotor field, a so-called detent torque is obtained, which ensures that when the motor is disconnected from the a.c. mains the rotor 6 occupies one of the two predetermined rest positions and does not remain in a position in which the driving torque passes through the value zero, in which position self-starting would be impossible.

In a known such self-starting two-pole single-phase synchronous motor with permanent magnetic rotor said rotor consists of a sintered anisotropic magnetic material, which gives rise to the aforesaid problems that the rotor must be subjected to a finishing operation. In contrast thereto, the rotor of the motor shown in the drawing is made of a plastics-bound anisotropic magnetic material, which makes it particularly easy to manufacture because such a material has substantially no tendency to deform. Therefore, such a rotor can be manufactured directly with effectively absolutely stable dimensions, so that no finishing operation is necessary. The plastics binder may be a thermoplastic one, such as that available under the name "Polyamid 6". As is known, the anisotropic magnetic material therein may be, for example, Ferroxdure.

Bonding the anisotropic magnetic material by means of a plastics material, however, results in the amount of anisotropic magnetic material in the rotor being smaller than in a rotor made of an anisotropic magnetic material only, This means that the attainable residual inducation is also reduced, which in particular has an adverse effect on the starting behaviour of a synchronous motor. Therefore, plastics-bonded anisotropic materials are not inherently suitable for the manufacture of rotors for such synchronous motors. In order to overcome this problem the two opposite pole faces of the rotor are confined so that each extends around the rotor circumference for a distance which subtends an angle smaller than 90° at the rotor axis; in practice it is found to be particularly advantageous if the said angle is approximately 65°. In this way the magnetic field is concentrated at pole faces of smaller surface area, so that the detent torque increases and the starting behaviour is improved considerably. Thus the influence of the smaller residual induction occurring in plastics-bonded anisotropic magnetic materials on the starting behaviour of the synchronous motor is compensated for, so that reliable starting behaviour can still be obtained. Such a configuration of the pole faces is obtained during the diametrical magnetization of the rotor, by employing a proportionally narrower magnetic field which only covers the desired distance around the rotor circumference during the magnetization process. This magnetic field expands again in the rotor itself, so that the field distribution in its interior is non-homogeneous. This type of rotor magnetization is possible because such a non-homogeneous field can be formed in plastics-bonded anisotropic magnetic materials without cracks forming in the material (as would occur with sintered anisotropic magnetic materials under the same conditions) because the particles to be magnetized can suitably orient themselves in the complete system. Figure 2 illustrates such a magnetization of the rotor 6, the pole faces, which are each limited in area so that each extends for a distance around the rotor circumference 10 which subtends an angle of less than 90° at the rotor axis 5, preferably an angle equal to 65° ± 10%, being represented schematically by the heavier lines 14

SPECIFICATION

Self-starting two-pole single-phase synchronous motor

The invention relates to a self-starting two-pole single phase synchronous motor comprising a permanent-magnetic rotor which has two opposite pole faces on its circumference as a result of diametrical magnetization and is arranged between two limbs of a stator provided with an exciter coil, the ends of said limbs partly enclosing the rotor so that air gaps are formed, said air gaps being collectively such that the magnetic field of the rotor will, when the motor is de-energized, produce a detent torque tending to drive the rotor to a rest position different from those at which the driving torque passes through zero in operation.

Such a motor, whose principle is for example described in German Patent Specification 14 88 270, should be capable of providing a large power output with a high efficiency, and the rotor should always start correctly from its rest position. To ensure reliable starting it is necessary that the rest position of the rotor always differs from the angular positions of the rotor at which the driving torque passes through the value zero. These zero-torque rotor positions occur when the rotor magnetic field is directed transversely of the limbs of the stator, so that there are two of such positions, these being angularly spaced from each other by 180° in accordance with the diametrical magnetization but being perfectly equivalent, because they only differ in respect of the orientation of the magnetic field. If particular rest positions are induced by suitably shaping the air gaps there will in fact be two of these rest positions, which are also 180° angularly spaced and are also perfectly equivalent. It is known to obtain the required angular deviation of the rest positions of the rotor from those positions in which the driving torque passes through the value zero by designing the ends of the stator limbs so that different air gaps relative to the rotor are formed for the two cases. Thus, for example, asymmetrically angularly displaced projections may be formed on the ends of the limbs. In conjunction with the magnetic field of the rotor this yields a so-called detent torque, which ensures that when the motor is disconnected from the a.c. mains the rotor occupies one of the two desired rest positions and does not remain in one of the two positions in which the driving torque passes through the value zero, which situation would prohibit self-starting.

In order to meet the above requirements the rotors of such self-starting two-pole single-phase synchronous motors, which are for example employed in domestic appliances such as citrus presses and the like, are normally manufactured from sintered anisotropic magnetic materials having a high residual inducation or remanence, because the value of this inducation is a determinent of both the power output and the detent torque which can be achieved. Such sintered anisotropic magnetic materials, however, have the disadvantage that they are liable to deform substantially during sintering, so that rotors thus manufactured have to be subjected to a finishing process which entails expensive grinding operations, because such materials are very hard. As a result of this, such synchronous motors become rather expensive, which restricts their use, especially in mass-produced products.

It is an object of the invention to provide a self-starting two-pole single-phase synchronous motor of the type set forth in the opening paragraph, which can be simple and cheap to manufacture and, despite this, can meet the requirements of a high power output and a reliable starting behaviour. To this end the invention is characterized in that the rotor is made of a plastics-bonded anisotropic magnetic material and the two opposite pole faces each extend around the rotor circumference for a distance which subtends an angle of less than 90° at the rotor axis.

It has now been recognized that plastics bonded anisotropic magnetic materials can be processed relatively easily in a dimensionally stable manner and need have no tendency to deform, so that the dimensions of the products manufactured with these materials can be sufficiently accurate that they require no finishing, which reduces the manufacturing costs. As a result of the plastics component used for bonding, the amount of anisotropic magnetic material present will inevitably be reduced, which means that such rotors have a lower residual induction and would thus be liable to have a poorer starting behaviour unless steps were taken to counteract this. This is the reason that it is arranged that the two opposite pole faces of the rotor each extend around the rotor circumference for a distance which subtends an angle of less than 90° at the rotor axis. This results in distinct magnet poles with a field concentration at the pole faces, so that the detent torque is increased, resulting in well-defined rest positions for the rotor and hence correct starting.

In this respect it should be noted that self-starting single-phase synchronous motors including rotors having a plurality of pole pairs, in which the opposite pole faces of a pole pair subtend a limited angle at the rotor axis, are already known, for example from United States Patent Specification 4,214,181. However, such rotors having a plurality of pole pairs and thus a plurality of directions of magnetization can only be manufactured from an isotropic magnetic material which has a substantially lower residual induction than an isotropic magnetic material which can only be magnetized in a diametrical direction, so that synchronous motors provided with such rotors are only capable of delivering smaller power outputs. It is apparent that such synchronous motors are of a construction which differs inherently from the type set forth in the opening paragraph and to which the present invention rotates. It should be noted that the use of plastics-bonded anisotropic magnetic materials for the manufacture of magnets is known *per se*.

In practice it has been found that it can be particularly advantageous if each said distance subtends an angle of approximately 65° at the rotor axis. This can result in a very favourable starting behaviour and a satisfactory power output.

and 15. The magnetization pattern inside the rotor 6 is represented by the broken lines 16. As can be seen, a field concentration is obtained on the diametrically opposed pole faces, which in the present case each extend in the circumferential direction for a distance which subtends an angle of 65° at the axis 5.

A method known *per se* such as, for example, extrusion or pressing may be used to manufacture a rotor from a plastics-bonded anisotropic magnetic material. In the present case it has been found that the injection-moulding process (which is known *per se*) is simple and effective for this purpose. As can be seen in Figures 3 and 4, this may be carried out using a tool which comprises a hollow cylindrical tool section 17 and a flat tool section 18, between which the tool parting face extends. In the hollow cylindrical tool section 17, whose cavity 19 defines the shape of the rotor, a conical insert 20 is arranged coaxially, which insert forms a bore in the finished rotor, into which bore the rotor shaft can be fitted. The tool section 17 further comprises ejectors 21 for ejecting the finished rotor, which ejectors are movable by means of a slide 22. The tool section 18 comprises a bore 23 which adjoins a further bore 25 formed in a terminating portion 24. An injection-moulding cylinder 26 can be applied to bore 25, the material to be processed reaching the cavity 19 of the tool section 17 therefore *via* the bores 25 and 23.

Two diametrically opposed pole-shoes 28 and 29 adjoin the circumference 27 of the tool section 17, which pole shoes are provided with exciter coils 30 and 31 respectively. In this way a magnetic field can be built up between the pole shoes 28 and 29, which field then extends diametrically in the direction of the arrow 32 through the tool (which is made of a non-magnetic material), an N-pole being formed at the location of one pole shoe and an S-pole at the location of the other pole shoe. As can be seen especially in Figure 4, the width of the pole shoes 28 and 29 has been chosen so that the homogeneous magnetic field issuing from the pole shoes only extends through a specific angular portion of the inner circumferential surface 33 of the tool section 17 which bounds the cavity 19, as is represented schematically by the broken lines 34 and 35. This defines the dimensions of the pole faces in the direction of the rotor circumference magnetization. Magnetization of the rotor is effected directly during the injection-moulding process, the individual particles of the anisotropic magnetic material being magnetized and being oriented in accordance with the magnetic field while the material injected into the cavity 19 of the tool is still in a plastic condition, which orientation is then maintained in the solid condition of the material. As a result of the specific choice of the width of the pole shoes 28 and 29, the magnetization pattern of the rotor as shown in Figure 2 is obtained. After the material has solidified by curing the plastics component, the magnetic field is switched off and the tool 17, 18 is divided at the tool parting face, the material disposed in the bore 23 of the tool section 18 being separated from the material disposed in the cavity 19 of the tool section 17. Subsequently, the rotor located in the cavity 19 of the tool section 17 is ejected from said tool section by means of the ejectors 21. The rotor is already in a finished state, because of the use of the plastics-bonded anisotropic magnetic material which strictly adopts the dimensions of the tool cavity.

As can be seen, the use of such a method enables the manufacture of a self-starting two-pole single-phase synchronous motor to be simple and cheap whilst, despite this, said motor can have a high power output and a reliable starting behaviour. The choice of the distance through which each pole face extends in the direction of the rotor circumference, and hence the angle subtended thereby at the rotor axis, is arbitrary for angles which are small relative to the maximum value of nearly 90°; for angles which are comparable with 90° it depends on the power rating of the synchronous motor. In principle the starting behaviour improves as smaller angles are chosen, but the power rating decreases. As already stated, it has been found in practice that an angle of approximately 65° is very favourable, because this can result in an absolutely reliable starting behaviour together with a satisfactory power rating.

CLAIMS

1. A self-starting two-pole single-phase synchronous motor comprising a permanent-magnetic rotor which has two opposite pole faces on its circumference as a result of diametrical magnetization and is arranged between two limbs of a stator provided with an exciter coil, the ends of said limbs partly enclosing the rotor so that air gaps are formed, said air gaps being collectively such that the magnetic field of the rotor will, when the motor is de-energized, produce a detent torque tending to drive the rotor to a rest position different from those at which the driving torque passes through zero in operation, characterized in that the rotor is made of a plastics bonded anisotropic magnetic material and the two opposite pole faces each extend around the rotor circumference for a distance which subtends an angle of less than 90° at the rotor axis.

2. A synchronous motor as claimed in Claim 1, characterized in that each said distance subtends an angle of approximately 65° at the rotor axis.

3. A synchronous motor substantially as described herein with reference to Figures 1 and 2 of the drawing.

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